IN THE CLAIMS:

Please cancel claims 1 - 19, and replace them with the attached claims 20 – 39.

REMARKS

Claims 20 - 39 are pending in the application.

Appropriate headings have been added to the specification, and claims from the literal translation have been replaced by claims drafted in conformity with U.S. Patent practice.

The application in its amended state is believed to be in condition for allowance. However, should the Examiner have any comments or suggestions, or wish to discuss the merits of the application, the undersigned would very much welcome a telephone call in order to expedite placement of the application into condition for allowance.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

On page 2, line 10, please amend the paragraph to read as follows:

A method according to the initially described type for activating the hydrogen acceptor complexes is described in US 5,786,233, whereby during the method the substrate is irradiated with short wave light, the photon energy of which is greater than the energy gap or band gap at the process temperature. The substrates are preferably heated to temperatures of approximately 650° C to 800° C for a duration of two to thirty minutes. In so doing, the complexes are broken up and the previously passivated acceptors (e.g. GaN:Mg) are activated, as a result of which the sheet resistance is reduced by up to several orders of magnitude, and the hole carrier concentration is correspondingly increased, respectively. As a result of the irradiation with short wavelength light, the activation of the acceptors and hence the hole carrier concentration were significantly increased. Since at still higher temperatures, however, the layer is thermally damaged and the p-diffusivity again decreases as the treatment duration increases, pursuant to US 5,786,233 a longer annealing is preferably used at comparatively low temperatures--.

On page 3, at line 4, please amend paragraph to read as follows:

--Yoichi Kamiura et al.; Jpn.J.Appl.Phys. 37 (1998) L970-L971 describes the influence of UV irradiation upon the Mg activation of GaN films. In this connection, the GaN films are held in a furnace for about one hour at a temperature greater than an activation temperature of about 550° C. Upon irradiation of the Mg doped GaN layer with UV radiation, the activation temperature can be reduced approximately by 100° C, as a result of which the thermal stress of the substrates is similarly reduced--.

On page 3, at line 11, please amend paragraph to read as follows:

--In EP 0723303, there is described a light-emitting electronic component that is built up of a hetero structure, and a method for producing the same, according to which at approximately 600° C with the aid of UV laser radiation, an annealing is carried out in order to increase the acceptor activation in the layers and to reduce the sheet resistance, respectively--.

On page 5, at line 6, please amend paragraph to read as follows:

--The first temperature of the inventive method is selected between 350° C and 900° C, whereby for example with Mg-containing GaN (or in general with group III nitrides) a temperature between 350° C and 600° C is preferred. Depending upon the type of semiconductor, the first temperature can also be a function of the selection of the third time interval and of the intensity of the electromagnetic radiation and of the generation of minority charge carriers connected therewith. As the length of the third time interval increases, and with increasing intensity of the electromagnetic radiation, then depending upon the type of semiconductor the first temperature can be decreased, which advantageously leads to a reduction of the thermal stress of the layer--.

On page 5, at line 19, please amend paragraph to read as follows:

--The second temperature during the second time interval is preferably selected between 700° C and 1400° C. The selection of this temperature depends to a considerable extent upon the material of the compound semiconductor, whereby for example with Mg-containing GaN a second temperature between 850° C and 1200° C is preferably selected. By selecting a higher second temperature, the second time interval can preferably be considerably shortened, which similarly again leads to a reduction of the thermal stressing of the semiconductor layer or of the semiconductor layer system.--

On page 8, at line 23, please amend paragraph to read as follows:

The inventive method is advantageously carried out, as mentioned above, by means of a rapid heating system (RTP System), since by means of the RTP system defined very short heating

processes can be carried out in the range of one second up to 30 minutes. The temperature-time curves of the substrates can be established precisely to the second in a temperature range of room temperature to about 1400° C, whereby the substrate can be heated extremely uniformly not only at low temperatures but also at high temperatures. Similarly, in RTP systems various process gases, which surround the substrate, can also be used, whereby the process gas pressure can be adjusted from vacuum conditions to overpressure conditions.

On page 9, between lines 5 and 6, please insert the following heading:

--Brief Description of the Drawings--;

On page 10, between lines 2 and 3, please insert the following heading:

--Description of Preferred Embodiments--.

On page 10, line 3, please amend paragraph to read as follows:

In Fig. 1, curve a, schematically shows a typical plot of a sheet resistance of a compound semiconductor, e.g. a GaN film that is treated or doped with Mg, as a function of the temperature. At low temperatures (e.g. GaN at less than approximately 550° C), the semiconductor film has a high electrical resistance R due to the passivation of the foreign atoms (e.g. Mg) by hydrogen. As the temperature increases, the resistance is reduced since more and more hydrogen-acceptor (foreign atom) complexes break up and the acceptors are thus electrically activated. If all of the complexes are broken up, and all acceptors activated, as the temperature increases from a lower temperature value T_L to an upper temperature value T_H, the sheet resistance remains nearly constant. Above the upper temperature value T_H, the sheet resistance R again significantly increases as the temperature increases, since above this temperature T_H a decomposition of the semiconductor layer occurs. For Mg doped GaN, at atmospheric pressure, T_L is approximately 550° C and T_H is approximately 1050° C.

On page 11, line 8, please amend paragraph to read as follows:

By generating minority charge carriers, the temperature T_L can be reduced. In this

connection, the charge carriers can be generated, for example, by irradiation with UV light, whereby the irradiated photon energy is greater that the energy gap of the semiconductor layer at the appropriate layer temperature. However, the charge carriers can also be generated, for example, by applying a potential or voltage to a semiconductor layer or to a semiconductor layer system, or by a combination of UV irradiation and applying a potential or a voltage to the layer or the layer system. The reduction of the lower temperature value T_L depends upon the number of charge carriers generated. The lower temperature value can be lowered by approximately 100° C by means of UV irradiation, for example in the case of GaN with a wave length of less than approximately 360nm as illustrated in Fig 1 by the curve b--.

On page 12, at line 3, please amend the paragraph to read as follows:

-- Fig. 2a shows an example of a temperature-time curve of the inventive method. The semiconductor layer or in general the semiconductor layer system is heated from room temperature (point A) as rapidly as possible to the temperature T_1, at which the sheet resistance of the semiconductor, or the sheet resistance of at least one layer of the semiconductor system, decreases (point B). Now for a first time interval of less than 120 seconds (time difference BE between B and E), the temperature of the layer (or at least one layer of the layer system) is held above the temperature T_1. Within this first time interval, the layer is heated for the duration of a second time interval (time difference CD between point D and C) to a second temperature T_2, whereby the second time interval is less than 60 seconds. Within this second time interval, the temperature-time curve can in general have any curve with fluctuations of up to 200° C about the second temperature T_2. Figure 2a shows for GaN a T_1 of about 550° C and a T_2 greater than the decomposition temperature of about 1050° C, for which reason the second time interval CD is less than 60 seconds, preferably less than 30 seconds. The lower threshold value for the second time interval is in general determined by the (closed loop) control rate with which the increasing portion of the temperature-time curve (ramp up) can be changed into the decreasing portion (ramp down).

For modern RTP systems, this time is approximately 1 second. Under certain conditions, this value can be lowered with future improvements of the RTP systems. The duration of the second time interval CD (in Fig 2a) decidedly determines how much the temperature T_2 can exceed the decomposition temperature T_H without permanently damaging the semiconductor layer or the layer system. The shorter the second time interval CD, the greater can be the temperature T_2, since then the overall thermal stressing of the layer does not exceed a critical value in the time interval CD. If the thermal stress is below this critical value, then depending upon the type of semiconductor, the vacancies and defects that are formed can to the greatest extent or at least in part be again eliminated by a subsequent annealing (tempering) at a temperature less than T_H. The critical value of the thermal stress of the layer or of the layer system is to be determined experimentally. So that as high a temperature T_2 as possible can be achieved at prescribed critical thermal stress, it is important that the RTP system enable a rapid heating up or cooling off of the semiconductor. Typical maximum heating rates are, depending upon the unit, between 75° C/s and 500° C/s. During the process illustrated in Fig 2a, charge carriers are generated within the layer for the duration of at least one third time interval by electromagnetic radiation, preferably by UV radiation. In this connection, the third time interval can be equal to the first time interval BE, as a result of which the free charge carriers are produced only if the Mg-(or in general foreign atom) hydrogen complexes are already nearly thermally broken up. Due to the (photo) generated free electrons, the diffusion characteristic of the broken-up hydrogen within the semiconductor layer can then be influenced. Alternatively, the third time interval can also embrace the second BE or the overall process AF. In general, the third time interval can be anywhere within the process AF, whereby its duration can be up to the overall process time AF. The lower limit of the third time interval is limited by the technical possibilities of providing an adequate UV light capacity. At the present this limit is approximately 10^{-9}s for pulsed lasers and approximately 10^{-6}s for flash lamps. However, time intervals of 1 to 120 seconds are preferred. It is particularly advantageous to set

the third time interval during the cooling-off phase such that during the cooling of the layer, a repassivation of the foreign atoms (e.g. the Mg in GaN) is extensively prevented. Furthermore, it is also advantageous during the heating-up phase, for example in the range AB or AC, to produce charge carriers by UV irradiation, as a result of which, as illustrated in Fig. 1, the first temperature T_1, and hence also the thermal stress of the semiconductor, can be reduced. Furthermore, within the process AF, charge carriers can be produced by UV radiation in a plurality of (third) time intervals. For example, the aforementioned advantages can be combined by producing charge carriers between AB or AC in ramp up and in ramp down.--

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20. A method of thermally treating at least one layer for actuating foreign atoms passivated in the layer by hydrogen, said method including the steps of:

heating said at least one layer, in a first time interval of less than 120 seconds, above a first temperature at which a specific sheet resistance decreases;

heating said at least one layer, in a second time interval which is within said first time interval and is less than 60 seconds, to above a decomposition temperature of said layer;

producing charge carriers in said at least one layer during at least one third time interval, by electromagnetic radiation.

21. A method according to claim 20, wherein said first temperature is between 300° C and 1200° C.

22. A method according to claim 21, wherein said second temperature is between 600° and 1200° C.

23. A method according to claim 20, wherein thermal method steps carried out beyond said first time interval at temperatures less than said first temperature.

24. A method according to claim 20, wherein said third time interval is partially beyond said first time interval.

25. A method according to claim 20, wherein said time interval is equal to said first time interval.

A2 cont.

26. A method according to claim 20, wherein said third time interval is beyond said first time interval.

27. A method according to claim 20, wherein said third time interval encompasses said second time interval.

28. A method according to claim 20, wherein said charge carriers are produced prior to said second time interval in terms of time.

29. A method according to claim 20, wherein said charge carriers are produced prior to and during said second time interval in terms of time.

30. A method according claim 20, wherein said charge carriers are produced during and after said second time interval.

31. A method according to claim 20, wherein said charge carriers are produced after said second time interval.

32. A method according to claim 20, wherein said charge carriers are produced only prior to and after said second time interval.

33. A method according to claim 20, wherein said charge carriers are produced within said second time interval.

34. A method according to claim 20, wherein at least one layer includes compound semiconductors of the group III-V.

35. A method according to claim 20, wherein at least one layer includes compound semiconductors of the group II-VI.

Ad Concluded

36. A method according to claim 20, wherein at least one layer includes compound semiconductors of the group III nitrides.

37. A method according to claim 20, wherein the energy of said electromagnetic radiation is greater than an energy gap of at least one layer.

38. A method according to claim 20, wherein thermal treatment of a layer is effected within an RTP system.

39. A method according to claim 20, wherein said second time interval is less than 30 seconds.